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CURV LINKAGE MANIPULATOR

by

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13. ABSTRACT

A spot-mounted, variable, rate-controlled hydraulic manipulator was developed for the cable-controlled undersea research vehicles, CURV II and CURV III. This manipulator incorporates a mechanical linkage arm which provides linear hand extension and eliminates disorienting cross-coupling of functions. The wrist is extremely compact, and is designed to further minimize cross-coupling. The hand is a synchronized, paralled jaw linkage. This combination of mechanical features is desirable from the standpoint of human factors. Control signals are encoded in binary, and are sent to a pressure-balanced, hydraulic-flow control package. This unit decodes the signals, and energizes hydraulic valves which control the magnitude and direction of flow to the appropriate actuators. This overall system is well adapted for operation in the corrosive and high-pressure undersea environment.

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AN ACTIVITY OF THE NAVAL MATERIAL COMMAND

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ADMINISTRATIVE INFORMATION

The design and fabrication of the CURV manipulator was a joint effort by members of the former Ocean Engineering Division (Fleet Engineering Department), under CURV program funding, and members of the Advanced Systems Division (Ocean Technology Department). Work was performed from January 1970 to December 1970.

Technical reviewers were J. L. Held and R. B. Fugitt.

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SUMMARY

PROBLEM

Design and construct a general-purpose electrohydraulic manipulator to be used by the cable-controlled underwater research vehicles, CURV's II and III.

RESULTS

A rate-controlled manipulator which has several advantages over existing systems was developed. These advantages and the mechanisms by which they are produced are discussed in this report.

RECOMMENDATION

When designing rate-controlled manipulators, consider the unique properties provided by the CURV manipulator.

INTRODUCTION

The need for teleoperators continues to increase as exploration moves from the laboratory into unknown environments. Mechanical hands must be used to extend the operator's reach whether the distance involved is several feet of high-pressure seawater or several million miles of vacuous space. Experience has shown that electrohydraulic manipulators are the best devices for work in the deep ocean.

Unfortunately, undersea manipulators have been excessively heavy and hard to control. A manipulator, which was designed for use on the cable-controlled undersea research vehicle (CURV), will eliminate these problems.

MECHANICAL FEATURES

The CURV manipulator has the prerequisite seven independent functions to qualify it as a manipulator (fig. 1). The order of these functions and the mechanisms by which they operate permit ease of operation. With this system, the operator is concerned only with the position and orientation of the manipulator hand and its opening and closing. The positions of the manipulator "elbow" and "arm" are not of concern. The elbow is always up, away from the bottom, and in a position least likely to interfere with work or viewing.

The order of actuators in the arm, or positioning portion of the manipulator, is azimuth (left and right), elevation, and extension. Because the elevation and azimuth axes practically intersect, the three functions are essentially independent. The linkage action causes the course travelled by the wrist during extension to be a straight line passing through the azimuth and elevation axes. Another portion of the linkage is a double parallelogram that maintains wrist orientation regardless of changes in elevation and extension of the arm. Thus, the arm performs the function of positioning the wrist, without disorienting it, in a spherical coordinate system.

Extending the hand of the conventional manipulator requires a complex trial-and-error combination of shoulder and elbow functions (fig. 2), and results in a hand orientation change which must be corrected by activating one or more wrist functions. Various techniques have been used, including position sensors and computerized control, to minimize these complications. The CURV manipulator linkage eliminates these problems automatically, requiring only one actuator for extension (fig. 3).

Another advantage of the linkage arm is its high section modulus, which makes it rigid but lightweight. The manipulator weighs only 75 lb, but can handle a 50-lb load at 55-in. extension.

The surface on which the wrist is mounted is always vertical, an advantage which leads to the following order of wrist actuators: yaw, pitch, and roll (progressing from the wrist-mounting plate to the hand). With this arrangement, the yaw axis is vertical; the pitch axis, horizontal; and all these axes intersect at a single point. This is desirable both for compactness and ease of operation. In addition, there is never any confusion concerning which wrist functions to activate to achieve a desired change in orientation.

The manipulator hand is a synchronous parallel jaw type. It is designed to grasp off-the-shelf diver tools to minimize the amount of modification required for using such tools. The distance between the grip location of the hand and the intersection of the wrist axes is minimized by driving only one side of the manipulator hand while a linkage synchronizes the action of the other.

CONTROL SYSTEM

The seven two-way functions require 14 command signals. Binary coding is used to minimize the number of conductors required to carry these signals and the necessary power to the hydraulic valves. This system requires only four digital power conductors and a return line or ground. The rate at which all functions operate is controlled by an additional analog channel. Thus, six conductors are required to operate this manipulator.

The control device consists of a rate-control potentiometer and four four-way switches or simple joy sticks (fig. 4). The joy sticks act essentially as 14 switches. These 14 commands are encoded in binary language by a system of diodes (fig. 5). Switch no. 10, for example, sends current to the conductors equivalent to "8" (binary: 1000) and "2" (binary: 10) which, in turn, activate the no. 8 and no. 2 relays on the vehicle. The signal current is also used to energize the relay contacts and, through them, the valve solenoid.

OTHER SPECIAL CHARACTERISTICS

The decoder and all valves are contained in the flow control package (fig. 6), which consists of a one-piece aluminum manifold and a lightweight cover filled with hydraulic fluid at ambient pressure. The porting of the manifold permits each four-way valve to be hydraulically in series with the servovalve. The vehicle to which the manipulator and flow control package are mounted supplies only the hydraulic power and the necessary six conductors.

As the upper arm approaches vertical, it creates mechanical interference with the shoulder gimbal. Before damage can occur, a mercury limit switch cuts off functions no. 3 (arm elevation) and no. 6 (arm withdrawal). A diode across the switch protects it from damage, due to inductive arcing, when a valve solenoid field collapses. Diodes across each solenoid similarly protect the relay contacts from arcing.

Synthetic materials are used when possible to minimize corrosion. All bushings are nylon, teflon, or fiberglass-reinforced teflon. Tubing and fittings are nylon. The manipulator structure is aluminum with a teflon-impregnated anodized surface. Some structural portions are stainless steel; however, these parts are isolated from the aluminum by plastics to prevent contact between dissimilar metals. For low cost and ease of replacement, commercially available hydraulic actuators are used with little modification. An epoxy-based paint is used to protect these actuators from galvanic corrosion.

FUTURE PLANS

A next-generation electrohydraulic manipulator is being designed at NUC. Operation of this manipulator will be similar to that of the mechanically-linked master-slave hot cell device. The operator will move the terminus (hand) of the controller (master) to the desired position and orientation, and the manipulator (slave) will follow. Forces encountered by the manipulator will be duplicated in the controller. Thus, the system will be terminus-controlled with bilateral position correspondence and force feedback. Analyses and tests have proven the feasibility of this concept. The positions of the controller and manipulator are compared, and the error of each actuator is measured. This error voltage is artificially "damped" by adding a value that is proportional to the rate of change or error. This signal is then converted to a proportional hydraulic force, both on the controller and the manipulator, tending to reduce the error.

CONCLUSIONS

The CURV rate-controlled linkage manipulator fills a wide gap in cost and complexity between previous rate-controlled undersea manipulators and future position-controlled manipulators. Compared with existing systems, it is smaller and requires less dexterity to operate.

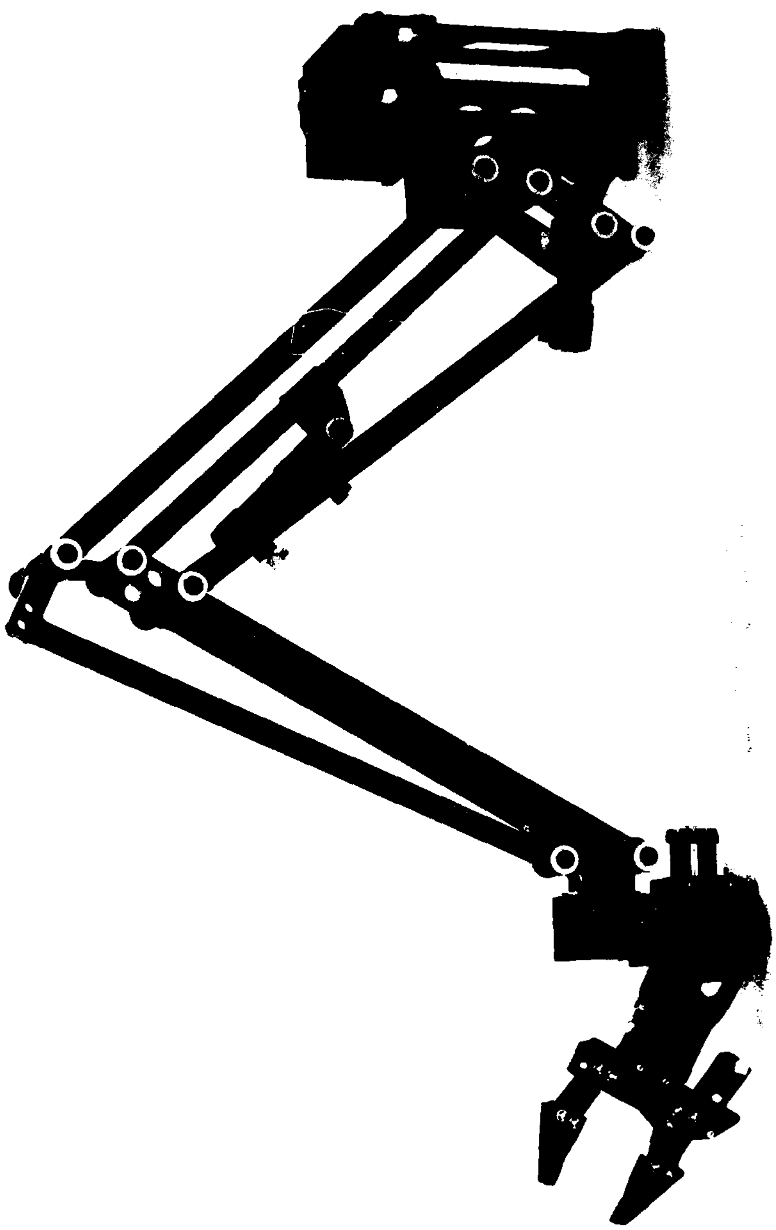


Figure 1. Linkage manipulator.

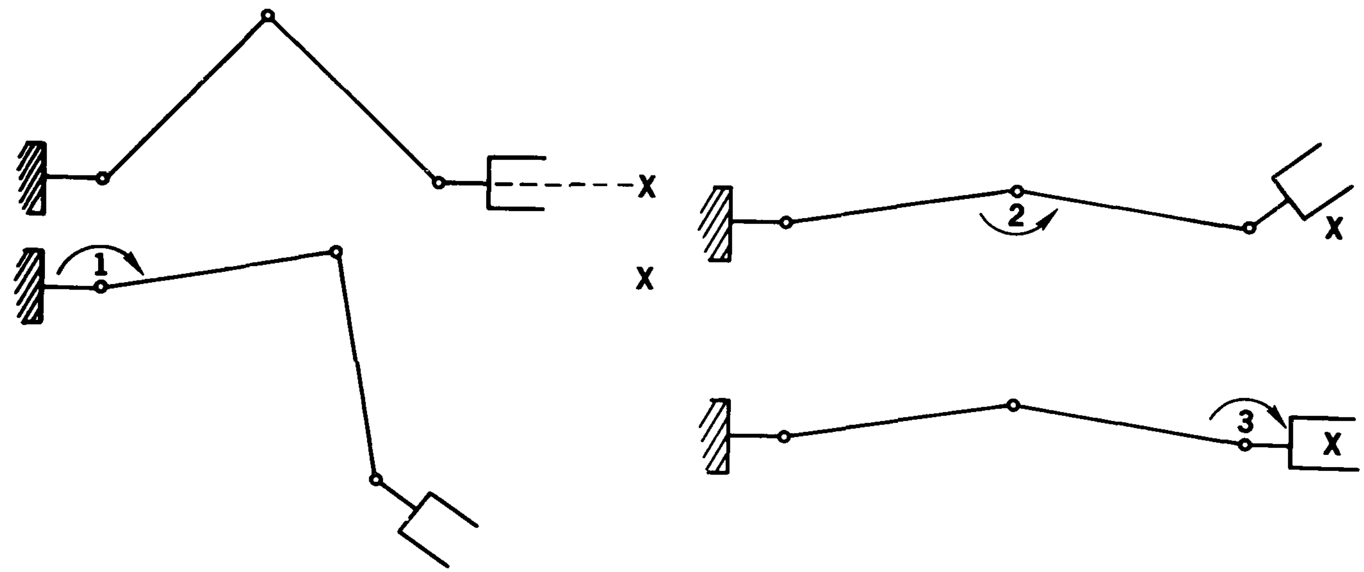


Figure 2. Extension of conventional manipulator.

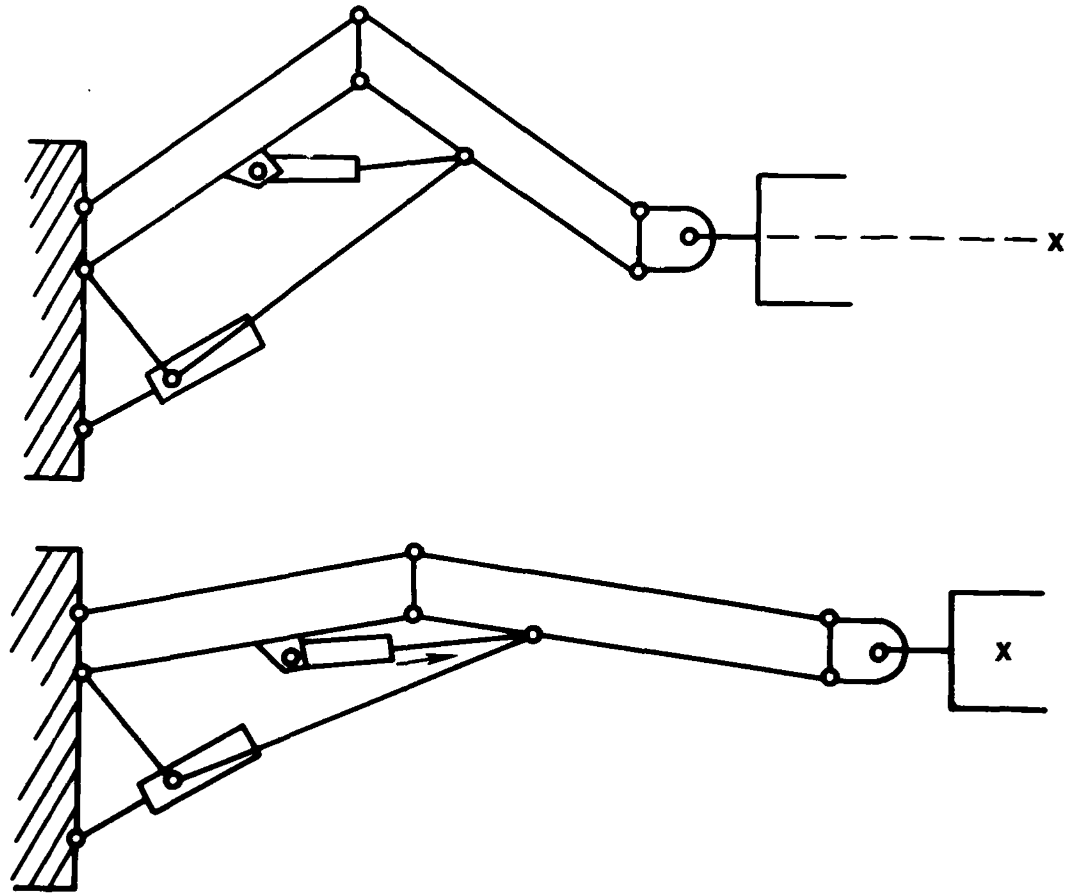
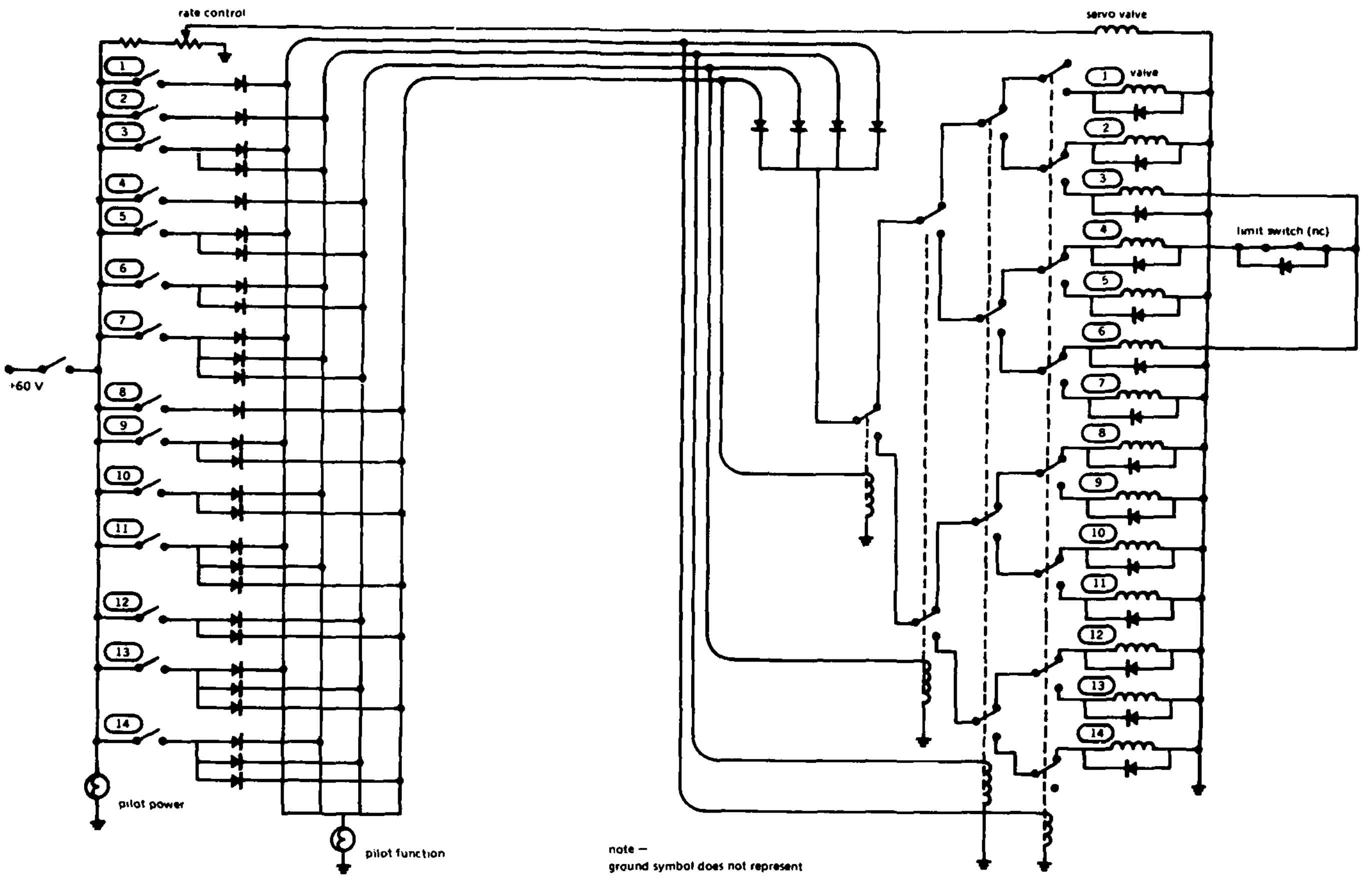


Figure 3. Extension of CURV manipulator.

Figure 4. Control box.



note –
ground symbol does not represent
chassis ground

Figure 5. Electrical schematic.

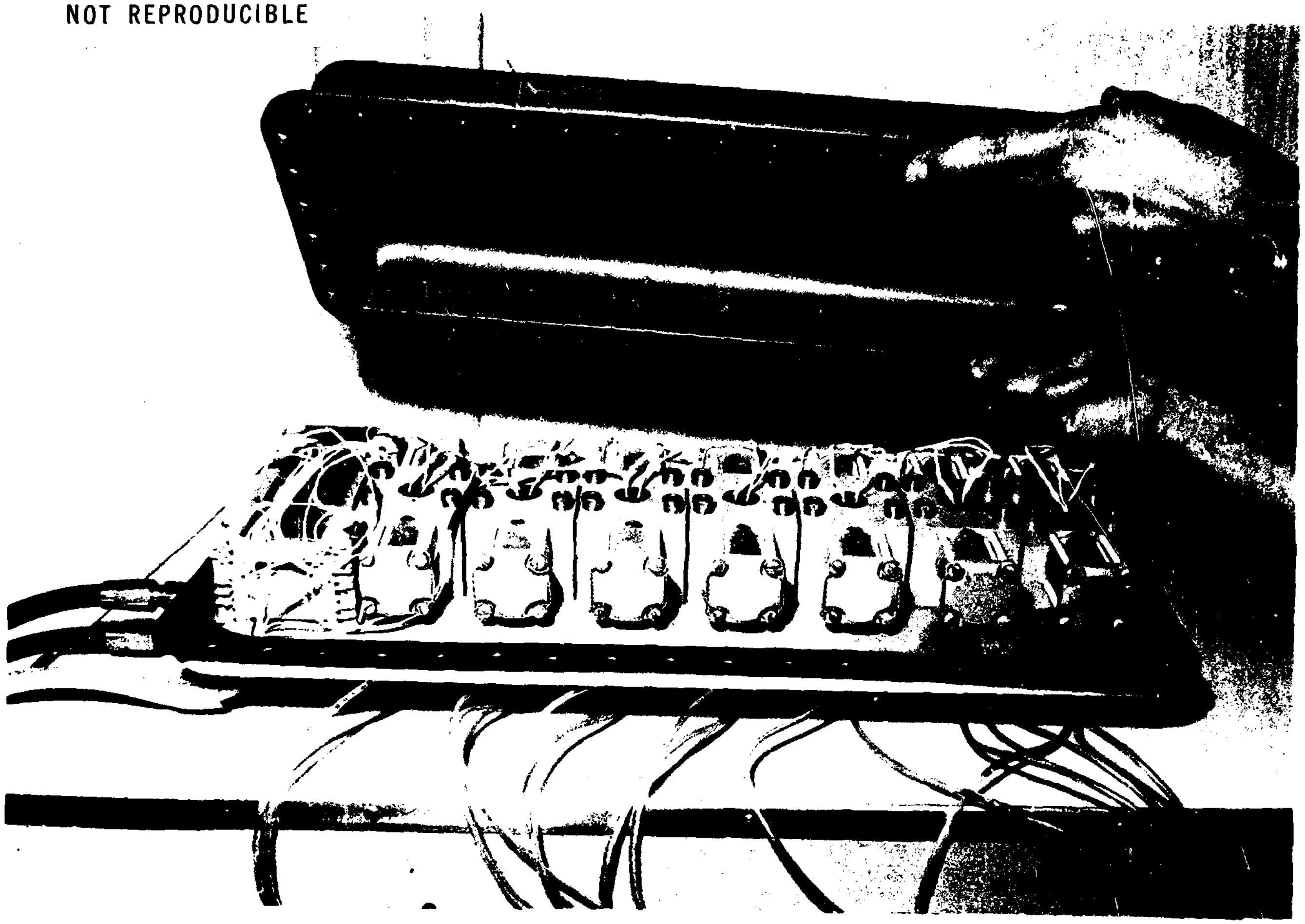


Figure 6. Flow-control package.